

THE EFFECT OF REGULAR EXERCISE ON COGNITIVE FUNCTIONING AND PERSONALITY**

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ABSTRACT

The effect of regular exercise on cognitive functioning and personality was investigated in 32 subjects representing 4 discrete groups based on sex and age. Before and after a 10 week exercise programme of jogging, calisthenics, and recreational activities, a test battery was administered to assess functioning in a number of domains: intelligence (WAIS Digit Symbol and Block Design); brain function (Trail-Making); speed of performance (Crossing-Off); memory and learning (WMS Visual Reproduction and Associate Learning); morale and life satisfaction (Life Satisfaction and Control Ratings); anxiety (MAACL); and depression (MAACL).

Improvement was observed on several physiological parameters. ANOVA revealed significant sex and age differences on Digit Symbol and Block Design and age differences on Trail-Making, Crossing-Off, Associate Learning, and anxiety. Regardless of sex and age, significant improvement in performance was observed from pre to post-test on Digit Symbol, Block Design, Trail-Making, Crossing Off, and on Associate Learning. In addition, an increase on health status rating ($p < .01$) and decrease in anxiety were observed from pre to post-test. These data illustrate beneficial effects of exercise on certain measures of cognitive functioning and personality.

INTRODUCTION

Cognitive functioning is, at least in cross-sectional studies, thought to decline with age (Botwinick, 1970; Botwinick, 1975) and several studies have demonstrated age differences in intellectual performance (Blum, Jarvick et al, 1970; Cunningham, Clayton et al, 1975; Furry and Bates, 1973; Horn and Cattell, 1967; Horn and Cattell, 1966; Schaie and Strother, 1968; Schaie and Labouvie-Vief, 1974). This decline with the resultant disabilities (including deterioration in mental health) is one of the most severe insults to the human organism by the ageing process. Forestalling its onset would be a major contribution to the quality of life of the older person.

Few studies have specifically investigated the effects of physical exercise on cognitive functioning. Gutin (1966) studied the effect of increased physical fitness on mental ability but found no significant relationship. McAdam and Wang (1967) found that subjects who exercised submaximally by running for ten minutes improved their performance significantly on a symbol substitution test compared with three non-exercising groups. Davey (1973) found that physical exertion

improved short term memory. Powell and Pohndorf (1971), in a study of 71 men (34 to 75 years) found that physical fitness was related positively to fluid intelligence scores. Elsayed, Ismail et al, (unpublished data) investigated the effect of a four month exercise programme on fluid and crystallized intelligence in 70 middle-aged men. They found high-fit individuals to be higher on fluid intelligence than low-fit individuals both before and after the programme. Significant increases in fluid intelligence were also observed from pre- to post-test.

It is commonly assumed that physical fitness is related to mental health but very few studies have investigated the effects of chronic physical exertion per se on mental well being. deVries and Adams (1972) compared single doses of moderate exercise with meprobamate (a commonly used tranquilizer for the treatment of anxiety tension states in middle-aged and older subjects). They found that exercise has a significantly greater effect upon the resting musculature than meprobamate without any undesirable side effects. Johnson and Spielberger (1968) observed that relaxation training reduced anxiety state, significantly. Stoudenmire (1972) however, noted that such training affects introverts more so than extroverts. Michael (1957) found that a physical fitness programme resulted in an increased ability to withstand emotional stress; similarly Jetté (1971) found that habitual exercisers were less anxious than non-exercisers. This study investigated the hypothesis that physical exercise is beneficial to behavioural function as determined by tests of cognition and mental health.

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METHODS

Subjects

Subjects were voluntary participants in an adult exercise programme conducted at Washington University in St. Louis. Four groups, consisting of 8 subjects each, were established on the basis of sex and age. They were designated:

GROUP	RANGE	MEAN	S.D.
♂ young	24-36	30.13	± 1.46
♂ middle-aged	49-61	53.00	± .65
♀ young	23-32	28.25	± 1.10
♀ middle-aged	43-62	50.25	± 2.54

Exercise Programme

The exercise programme was conducted for one hour three times a week for ten weeks. Following a five minute warm up period, subjects participated in group calisthenics designed to benefit all major muscle groups, followed by a walking/jogging programme designed to elicit approximately 70% of maximal working capacity. While retaining the basic format and sequence, the intensity of exercise became progressively more strenuous toward the end of the programme.

Based on pre-programme physicians' evaluation and medical history questionnaire, three groups were established and an exercise leader was assigned to each group so that appropriate exercise prescriptions could be made and supervised. Following calisthenics each subject reported to the respective group. As a safety measure, and to insure that the age-related training intensity was reached during jogging, all subjects monitored their own heart rates. The majority of subjects started jogging only part of a lap, but progressed to as much as four miles by the end of the programme.

General Testing Procedure

Data were collected on all subjects in the first and final weeks of the programme. On each occasion they reported to the Exercise Physiology/Psychology Laboratory where they completed a battery of tests designed to assess functioning in several cognitive and personality domains. The battery was relatively undemanding, was administered by trained assistants, and was completed within 25 to 40 minutes.

Subjects then rested quietly in the supine position for 5 minutes. Heart rate and systolic and diastolic blood pressures were measured using standard clinical procedures at the end of the 5 minute rest. In addition, height and weight were obtained and percent lean body weight was estimated using the method of Wilmore and Behnke, (1969) for males and the body density predictive equation of Pollock, Laughridge et al, (1975) for females.

The subject then walked on a treadmill for 10 minutes at 2.5 mph with the grade being increased 2 degrees every two minutes to a maximum of eight degrees. Fifteen seconds before the end of the tenth minute the subject's exercise heart rate was recorded. The treadmill was then stopped and exercise blood pressure was immediately measured using the indirect cuff method.

Variables

Pre- and post-programme data were collected on the following variables:

Physiological

1. Age (years) (AGE)
2. Height (cms) (HT)
3. Weight (kgs) (WT)
4. Percent lean body mass (% LBM)
5. Resting heart rate (beats/min) (RHR)
6. Resting systolic blood pressure (mmHg) (RSBP)
7. Resting diastolic blood pressure (mmHg) (RDBP)
8. Submaximal heart rate (beats/min) (SHR)
9. Submaximal systolic blood pressure (mmHg) (SSBP)
10. Submaximal diastolic blood pressure (mmHg) (SDBP)

Cognitive

11. Digit Symbol subtest, Wechsler Adult Intelligence Scale (WAIS) (Wechsler, 1955) (DIGIT)
12. Block Design subtest, (WAIS) (Wechsler, 1955) (BLOCK)
13. Trail Making Test (Armitage, 1946) (TRAIL)
14. Crossing-Off (Botwinick and Storandt, 1973) (XOFF)
15. Visual Reproduction subtest, Wechsler Memory Scale (WMS) (Wechsler, 1945) (VISUAL)
16. Associate Learning subtest (WMS) (Wechsler, 1945) (ASSOC)

Personality

17. Life Satisfaction Rating (Botwinick and Storandt, 1974) (STATUS)
18. Control Rating Scale (Botwinick and Storandt, 1974) (CONT)
19. Health Rating Scale (Botwinick and Storandt, 1974) (HEALTH)
20. Anxiety Scale (MAACL) (Zuckerman and Lubin, 1965) (ANX)
21. Depression Scale (MAACL) (Zuckerman and Lubin, 1965) (DEP)

The physiological measures have been shown to discriminate between different physical fitness conditions and age groups. In addition, several are utilized in the estimation of physical fitness. The cognitive and personality test battery was designed to assess functioning in a number of domains: intelligence (WAIS Digit Symbol and Block Design); brain function (Trail-Making); speed

of performance (Crossing-Off); memory and learning (WMS Visual Reproduction and Associate Learning); morale and life satisfaction (Life Satisfaction and Control Ratings); and perception of one's own health status (Health Rating Scale); and anxiety (MAACL); and depression (MAACL).

Statistical Procedures

ANOVA was employed to determine the effect of the exercise programme on the physiological, cognitive and personality variables between and within the sex and age groups. Whenever significance was found the means were analyzed by the Newman-Keuls procedure to determine the means responsible or contributing to the significant results obtained.

RESULTS

The means and standard errors for the physiological data are presented in Table I. When ANOVA was applied to the data (Table II), significant sex differences were found on weight ($p < .01$), percent lean body mass ($p < .01$), RSBP ($p < .05$) and SHR ($p < .01$) and significant age differences on RDBP ($p < .01$), SDBP ($p < .05$). The significant SAT interaction on SHR was due to the highly significant difference between the

middle aged male group at the post-test and the young female group at the pre-test. Regardless of sex or age, significant improvement was observed from pre to post-test on RSBP ($p < .01$), RDBP ($p < .05$) and SHR ($p < .05$). These data reflect the positive effect of the exercise programme both anthropometrically and cardiovascularly.

The means and standard errors for the cognitive data are presented in Table III. ANOVA (Table IV) revealed that compared with men, women scored significantly ($p < .05$) better on Digit Symbol and less well on Block Design and Visual Reproduction. As was expected, older subjects scored significantly poorer ($p < .01$) on Digit Symbol, Block Design, Crossing-Off, Associate Learning, and also Trail-Making ($p < .05$). However, regardless of sex or age at the end of the programme significant improvement ($p < .01$), was observed on Digit Symbol, Block Design, Trail-Making and Crossing-Off, and also on Associate Learning ($p < .05$). The significant SA interaction on Digit Symbol reflects the marked higher scoring by the female young group compared with the other three groups. The significant SAT interaction on Crossing-Off was due to the mean of the male middle aged group being so low compared with other pre and post-programme means. Conversely, the significant SAT

TABLE I
Pre and Post-Programme Physiological Data

Variable	Male				Female			
	Young (n=8)		Middle-aged (n=8)		Young (n=8)		Middle-aged (n=8)	
<i>Pre-Programme</i>	\bar{X}	SE	\bar{X}	SE	\bar{X}	SE	\bar{X}	SE
1. Age	30.13	1.46	53.00	1.65	28.25	1.10	50.25	2.54
2. Height	72.03	1.06	70.25	.84	65.97	1.09	62.88	.66
3. Weight	172.94	10.90	182.50	7.50	140.69	6.53	137.69	6.81
4. % LBM	82.83	2.09	82.40	1.00	73.15	1.54	71.88	2.29
5. RHR	64.00	1.85	66.13	2.97	67.25	4.34	66.00	2.51
6. RSBP	132.75	3.36	139.75	6.46	120.38	4.18	128.75	4.36
7. RDBP	81.25	3.52	88.25	2.55	73.75	3.43	82.00	2.39
8. SHR	114.50	3.48	114.25	5.16	138.25	5.86	128.75	4.49
9. SSBP	149.38	4.87	155.25	7.86	138.63	5.79	170.63	9.83
10. SDBP	80.75	3.52	90.38	2.45	82.38	5.71	84.75	3.38
<i>Post-Programme</i>								
1. Age	—	—	—	—	—	—	—	—
2. Height	—	—	—	—	—	—	—	—
3. Weight	172.50	11.29	177.75	9.62	141.50	6.65	137.38	7.76
4. % LBM	83.49	2.06	83.16	1.29	72.16	1.64	70.56	2.62
5. RHR	68.75	2.44	67.38	2.64	65.75	.96	70.25	4.10
6. RSBP	129.63	3.42	131.75	4.35	117.75	4.23	126.88	6.85
7. RDBP	75.50	3.20	84.88	4.45	70.88	2.50	79.63	3.79
8. SHR	112.50	3.16	109.25	2.67	123.25	6.23	131.50	5.53
9. SSBP	150.88	4.29	162.25	5.97	140.88	3.91	169.88	13.38
10. SDBP	81.25	5.15	88.25	2.79	76.63	2.24	86.50	3.22

TABLE II
ANOVA Of Physiological Data

	d.f.	Wt.	% Lean	RHR	RSBP	RDBP	SHR	SSBP	SDBP
<i>Between SS</i>									
Sex (male vs. female)	1	19.38**	36.79**	.11	5.14*	3.99	17.46**	.01	.76
Age (young vs. middle-aged)	1	.05	.25	.20	2.26	7.96**	.08	7.84**	5.91*
SA	1	.42	.80	.08	.22	.00	.02	2.45	.14
Error	28								
<i>Within SS</i>									
Time (pre vs. post)	1	.55	.20	1.41	4.32**	6.04*	5.39*	.68	.38
ST	1	.82	3.49	.19	.78	.44	.40	.33	.07
AT	1	.75	.01	.09	.30	.24	3.17	.04	.29
SAT	1	.22	.04	1.57	.56	.10	6.27*	.49	1.23
Error	28								

** 7.64 = $p < .01$

* 4.20 = $p < .05$

TABLE III
Pre and Post-Programme Cognitive Data

Variable	Male				Female			
	Young (n=8)		Middle-aged (n=8)		Young (n=8)		Middle-aged (n=8)	
<i>Pre-Programme</i>	\bar{X}	S.E.	\bar{X}	S.E.	\bar{X}	S.E.	\bar{X}	S.E.
11. Digit Symbol	61.38	1.84	58.13	4.12	72.25	3.28	58.75	3.16
12. Block Design	43.88	1.81	40.63	1.67	40.63	1.86	35.38	2.74
13. Trail-Making	47.20	1.57	33.12	2.95	41.75	4.50	36.71	4.02
14. Crossing-Off	17.60	1.13	13.20	.75	17.04	.99	16.00	.66
15. Visual Repro.	13.25	.49	12.75	.73	11.38	.98	10.13	1.19
16. Assoc. Learning	16.69	.87	17.31	.62	18.31	.40	14.44	1.20
<i>Post-Programme</i>								
11. Digit Symbol	66.00	2.04	63.25	3.27	80.75	3.89	63.25	3.17
12. Block Design	46.88	.52	42.63	1.49	44.75	1.66	39.00	1.58
13. Trail-Making	49.44	5.17	44.27	5.28	55.75	4.80	44.10	6.78
14. Crossing-Off	18.88	1.58	15.77	.82	18.74	1.02	16.43	.78
15. Visual Repro.	13.88	.13	12.75	.86	12.63	.71	11.00	1.24
16. Assoc. Learning	18.94	.68	16.00	.91	18.81	.72	17.50	1.24

interaction on Associate Learning was due to the mean of the female middle aged group being so low at pre-test compared to the other means.

The means and standard errors for the personality data are presented in Table V. ANOVA (Table VI) showed significant ($p < .05$) age differences on anxiety and depression in favour of the older subjects. Regardless of sex or age, a significant improvement in Health Status Rating ($p < .01$) and reduction in anxiety ($p < .05$) was observed from pre to post-test. The significant SAT interaction on Control Rating reflects an increase in control rating by the female young group and a decrease by the female middle aged group. The signifi-

cant AT interaction on anxiety was due to a marked decrease in the mean anxiety score of the young subjects from pre to post-test. In contrast, no change was observed in the middle aged group.

DISCUSSION

This study investigated the effect of regular exercise on cognitive functioning and personality in four discrete groups based on sex and age. The test battery used was chosen because the literature indicates that age is related to assessments in those areas and because the basic hypothesis of the study was that cognitive capabilities and mental health are influenced in a positive manner by the exercise programme described earlier.

TABLE IV
ANOVA of Cognitive Data

	d.f.	Digit Symbol	Block Design	Trail Making	Crossing Off	Visual Repro	Associate Learning
<i>Between SS</i>							
Sex	1	4.95*	6.23*	.07	.52	5.65*	.00
Age	1	9.83**	10.49**	5.20*	8.01**	2.03	6.93**
SA	1	4.49*	.38	.03	1.17	.16	1.02
Error	28						
<i>Within SS</i>							
Time	1	23.86**	9.66**	12.90**	26.57**	3.99	4.97*
ST	1	.49	.45	.68	2.18	1.18	1.69
AT	1	.57	.13	.06	.00	.53	.25
SAT	1	.93	.02	2.57	4.90*	.03	9.21**
Error	28						

** 7.64 = $p < .01$ * 4.20 = $p < .05$

TABLE V
Pre and Post-Programme Personality Data

Variable	Male				Female			
	Young (n=8)		Middle-aged (n=8)		Young (n=8)		Middle-aged (n=8)	
<i>Pre=Programme</i>	\bar{X}	S.E.	\bar{X}	S.E.	\bar{X}	S.E.	\bar{X}	S.E.
17. Satisfaction	6.50	1.12	8.50	.42	6.00	1.39	7.50	.73
18. Control	7.25	.70	8.00	.63	6.38	.80	8.63	.42
19. Health Rating	6.75	.75	7.63	.60	5.63	.80	7.38	.53
20. Anxiety	8.38	2.28	4.13	1.23	7.63	1.19	3.25	.80
21. Depression	12.75	3.55	7.63	1.79	15.25	3.21	6.75	1.63
<i>Post-Programme</i>								
17. Satisfaction	6.88	1.01	8.88	.35	6.63	.87	6.87	.81
18. Control	8.00	.57	8.25	.53	7.88	.30	8.75	.37
19. Health Rating	6.63	.98	8.25	.31	6.88	.67	5.88	1.09
20. Anxiety	6.63	2.41	3.63	1.19	5.75	.92	3.75	1.22
21. Depression	11.88	3.56	7.63	2.13	12.50	2.16	8.88	2.30

TABLE VI
ANOVA of Personality Data

	d.f.	Life Satisfaction	Health Status	Control Rating	MAACL Anxiety	MAACL Depression
<i>Between SS</i>						
Sex	1	1.28	.00	1.84	.16	.14
Age	1	3.02	4.07	1.59	5.37*	5.21*
SA	1	.46	1.08	.46	.02	.09
Error	28					
<i>Within SS</i>						
Time	1	.89	8.06**	.02	6.01*	.25
ST	1	.88	.46	.23	.35	.01
AT	1	2.47	4.11	1.64	6.01*	3.65
SAT	1	2.47	.89	5.04*	.58	1.77
Error	28					

** 7.64 = $p < .01$ * 4.20 = $p < .05$

The physiological data indicated that the exercise programme was effective in improving the anthropometric status and cardiovascular function of the subjects. This was particularly the case for female and older subjects (Table I).

Since only a small number of subjects were used in this study, it is recommended that the study be repeated using larger numbers in each group in order to ascertain the stability of the findings.

The middle aged subjects scored less well on several cognitive measures. This was to be expected since the Digit Symbol subtest of the WAIS consistently shows relative decline with increased age and is thought to reflect the "normal" age related decline in perceptual-psychomotor intelligence. The Block Design subtest also shows age related decline. Older adults typically perform less well on the Trail Making test than do the young. For example, previous research indicates it is useful in differentiating those older adults who are "played out" as opposed to those who are "vital" (Storandt, Wittells et al, 1975). However, it should be noted that the subjects in this study were not aged. One of the most well documented age related deficits in performance has to do with slow response speed in older persons. Several investigators suggest the decrease in ability to respond quickly is a reflection of central nervous system function (see Botwinick, 1973, chapter 12, for example). The Crossing-Off test used in this study is a simple measure of psychomotor speed and poses little in the way of cognitive demands upon the subject.

Difficulty with memory is frequently seen as an age related symptom of distress and pathology. Two measures designed to tap deficits in this area were included in the battery. Both are standard measures from the Wechsler Memory Scale — Visual Reproduction, a measure of non-verbal memory, and Associate Learning. Typically (as was the case in this study) older adults find paired associates learning most difficult, as compared to other types of verbal learning and memory.

It is interesting to observe marked improvements in performance on most of the cognitive measures after the exercise programme. They suggest improvements in per-

ceptual psychomotor intelligence, neuropsychological function, psychomotor speed, and associate learning.

Several authors have attempted to relate decrements in cognitive functioning to insufficiency of oxygen transport as a result of cardiovascular disease (Spieth, 1965). Jacobs (1969) demonstrated considerable improvement in short term memory and conceptualization tests administered to 13 elderly males (mean 68 years) 24 hours after intermittent exposure to 2.5 atmospheres absolute of 100 percent oxygen. It is generally considered that oxygen itself does not play the major role in cerebral functioning (Libow, 1974; Sokoloff, 1966; Sokoloff, 1976); however, it may be implicated in the changes in brain chemistry that accompany ageing. Sokoloff, (1966) compared a group of healthy elderly men with objective evidence of minimal asymptomatic arteriosclerosis and found marked reductions of cerebral blood flow, evidence of decreased O₂ tension in the brain, and greater deficits in cognitive, perceptive, and other psychological functions. Besides sufficiency of oxygen, cognitive functioning is also dependent on the availability of circulating glucose as a nutrient to the brain. Physical training has an effect on the physiological and biochemical processes by which energy is produced and made available to different parts of the body, including the brain. There is reason to believe that when individuals become habitual exercisers as well as physically fit they are likely to have an abundance of circulating glucose which can be transported efficiently (in this case to the brain) for nourishment.

Meir-Ruge, Emmenegger et al (1975) maintain that the fundamental mechanisms in ageing are mediated more by metabolic changes than by circulatory disturbances. An exercise programme has distinct and well documented physiological, biochemical and psychological effects (Ismail and Young, 1977; Young and Ismail, 1977). Some of these psychological effects were demonstrated in this study (Table VI). To the extent that decline in cognitive functioning with age is the result of physiological and biochemical changes, it is not unreasonable to expect improvements in cognitive functioning as physiological and biochemical improvements occur with exercise. Similarly, improvements in mental health can be expected.

REFERENCES

- Armitage, S. G., 1945 "An analysis of certain psychological tests used for the evaluation of brain injury". *Psych. Monographs* 60 (1) (Whole No. 277).
- Baltes, P. B. and Labouvie, G. V., 1945 "Adult development of intellectual performance. Description, explanation, modification". In C. Eisdorfer & M. P. Lawton (Eds) *The Psychology of Adult Development and Aging*, American Psychological Association.

- Blum, J. E., Jarvick, L. F., and Clarke, E. T., 1970 "Rate of change on selective tests of intelligence: A twenty year longitudinal study of aging". *J.Gerontol.* 25: 171-176.
- Botwinick, J., 1970 "Geropsychology". *Ann.Rev.Psych.* 21: 239-272.
- Botwinick, J., 1973 "Aging and Behavior". New York: Springer Publishing Co.
- Botwinick, J., and Storandt, M., 1973 "Speed functions, vocabulary ability, and age". *Per.Motor Skills* 36: 1123-1128.
- Botwinick, J. and Storandt, M., 1974. *Memory related functions and age*, Springfield, Illinois: Charles C. Thomas.
- Botwinick, J. 1975 "Behavioral Processes in Aging". Vol. 2, eds: Gershon, S. and Raskin, A., Raven Press, New York.
- Brinley, J. F. and Fichter, J., 1970 "Performance deficits in the elderly in relation to memory level and set". *J.Gerontol.* 25: 30-35.
- Cunningham, R. W., Clayton, V. and Overton, W. 1975 "Fluid and crystallized intelligence in young adulthood and old age". *J.Gerontol.* 30: 53-55.
- deVries, H. A. and Adams, G. M. 1972 "Electromyographic comparison of single doses of exercise and meprobamate as to effects on muscular relaxation". *Amer.J.Phys.Med.* 51: 130-141.
- Elsayed, M., Ismail, A. H., and Young, R. J. "Intellectual differences of adult men related to age and physical fitness before and after an exercise program". (Submitted for publication).
- Furry, A. C. and Bates, B. P. "The effect of age differences in ability — extraneous performance variables in the assessment of intelligence in children, adults and elderly". *J. Gerontol.* 28: 73-80.
- Gutin, B. 1966 "Effect of increase in physical fitness and mental ability following physical and mental stress". *Research Quarterly* 37: 211-212.
- Horn, J. L., and Cattell, R. B. 1967 "Age differences in fluid and crystallized intelligence". *Acta.Psychologia* 26: 107-129.
- Horn, J., and Cattell, R. B. "Age differences in primary mental ability factors". *J.Gerontol.* 21: 211-220.
- Ismail, A. H., and Young, R. J. 1977 "Effect of chronic exercise on the multivariate relationships between selected biochemical and personality variables". *Mult.Behav.Res.* 12: 49-67.
- Jacobs, E. A. 1969 "Hyperoxygenation effect on cognitive functioning in the aged". *N.Eng.J.Med.* 281: 753-757.
- Jetté, M. 1971 "A blood serum personality trait profile of habitual exercisers". *Proceedings of the Joint Meeting of The Canadian Assoc.Sports Sci.and the American College of Sports Medicine*, Toronto, Canada.
- Labouvie-Vief, G. 1974 "Man-environment relations and intellectual behavior in later life". Paper presented at annual meeting of the APA, New Orleans.
- Labouvie-Vief, G., Hayes, W. J., Baltes, P. B. 1974. "Operant analysis of intellectual behavior in old age". *Human Development* 17: 259-272.
- Labouvie-Vief, G., and Gonda, J. N. 1976 "Cognitive strategy training and intellectual performance in the elderly". *J.Gerontol.* 31: 327-332.
- Libow, L. S. 1974 "Interaction of medical, biologic, and behavioral factors on aging, adaptation, and survival". An 11 year longitudinal study. *Geriatrics* 29: 75-88.
- McAdam, R., and Wang, K. W. 1967. "Performance of a simple mental task following various treatments". *Research Quarterly* 38: 208-212.

- Meir-Ruge, R., Emmenegger, H. and Gyax, P. 1975. "Experimental pathophysiology and pharmacology in basic research of the aging brain". *Psychopharmacol.Bull.* 11: 46-48.
- Michael, D., Jr. 1957 "Stress adaptation through exercise". *Research Quarterly* 28: 50-54.
- Pollock, M. L., Laughridge, E. E., Coleman, B., Linnerud, A. C. and Jackson, A. 1975 "Prediction of body density in young and middle-aged women". *J.Appl.Physiol.* 38: 745-749.
- Powell, R. R., and Pohndorf, R. H. 1971 "Comparison of adult exercisers and non-exercisers on fluid intelligence and selected physiological variables". *Research Quarterly* 42: 70-77.
- Schaie, K. W. and Strother, C. R. 1968 "A cross-sequential study of age changes in cognitive behavior". *Psychol.Bull.* 70: 671-680.
- Schaie, K. W. and Labouvie-Vief, G. 1974 "Generational versus ontogenetic components of change in adult cognitive behavior: a fourteen year cross-sequential study". *Developmental Psychol.* 10: 305-320.
- Schaie, K. W. 1974. "Translation in gerontology: From lab to life: Intellectual functioning". *American Psychologist* 29: 802-807.
- Sokoloff, J. 1966 "Cerebral circulation and metabolic changes associated with aging". *Res.Publ.Assoc. Res.Nerv.Ment.Dis. (Baltimore)* 41: 237-254.
- Sokoloff, L. 1976 "Cerebral circulation and metabolism in the aged". *Psycho-pharmacol.Bull.* 11: 45-46.
- Spieth, E. 1965 "Slowness of task performance and cardiovascular diseases". In A. T. Welford and James E. Birren (Eds.) *Behavior aging and the nervous system*. Springfield, Illinois. Charles C. Thomas Co.
- Storandt, M., Wittells, I., and Botwinick, J. 1975 "Predictors of a dimension of well-being in the relocated healthy aged". *J.Gerontol.* 30: 97-102.
- Stoudenmire, J. 1972. "Effects of muscle relaxation training on state and trait of anxiety in introverts and extroverts". *J.Pers.Social Psy.* 24: 273-275.
- Wechsler, S. 1976 "A standardized memory scale for clinical use". *J.Gerontol.* 31: 314-317.
- Wechsler, S. 1955. *Wechsler Adult Intelligence Scale: Manual*. New York: The Psychological Corporation.
- Wilmore, J. E., and Behnke, A. R. 1969. "An anthropometric estimation of body density and lean body weight in young men". *Journal of Applied Physiology* 27: 25-31.
- Young, R. J., and Ismail, A. H. 1977 "Comparison of selected physiological and personality variables in regular and non-regular adult male exercisers". *Research Quarterly* 48: 617-622.
- Zung, W. W. K. 1967 "Depression in the normal aged". *Psychosomatics* 8: 287-292.
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